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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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THE BRITISH WEST INDIAN LIMES INDUSTRY.*

FOR some years prior to 1938 the market outlook for British West Indian lime products had become so uncertain that various sections of the industry organised themselves cooperatively in order to meet the situation. The first step taken was the formation, in 1935, of the West Indian Lime Oil Sales Company, Limited, the initial members of which were the lime oil producers of Trinidad, Tobago and St. Lucia. The main purpose of this Company was to establish an intercolonial system of collective marketing of lime oil. This Company, however, was not intended nor suitably constituted to undertake the task of promoting general cooperative action within the industry. In 1938, therefore, at a meeting of representatives of a large majority of those engaged in the industry it was decided to bring about the formation of a central West Indian cooperative limes Association. After several difficulties had been overcome the West Indian Limes Association (Incorporated) was registered in Trinidad in February 1941, the original subscribing members being the Dominica Limes Association, the St. Lucia Limes Association and the Trinidad and Tobago Limes Association Limited. The West Indian Lime Oil Sales Company Limited, was admitted to membership of the new Association just before the latter's first annual general meeting which has just been concluded at the Imperial College of Tropical Agriculture.

Many important aspects of the limes industry in the British West Indies were discussed at this meeting. As was to be expected the discussions centred chiefly on cooperative action because the future development and welfare of the industry must in a large measure depend upon the degree of cooperation which can be achieved among the various sections of the industry. The opportunity was also taken to define the objectives of the new Association and to prepare an initial programme of work. In order to provide the Association with a source of funds for carrying out several of the recommendations included in this programme it was decided to invite the Governments of the Colonies concerned to impose a levy on exports of the limes industry.

* Report of an Extraordinary General Meeting and of the First Annual General Meeting of the West Indian Limes Association (Incorporated), held in Trinidad, April, 1941. Price 3*s*. To be obtained from the Agricultural Advisory Department, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

It was generally accepted that the fostering of co-operative marketing within the British West Indies limes industry was one of the chief objectives of the Association. It was decided, accordingly, to issue a special appeal to all producers and exporters of lime oil, who do not at present market lime oil through the West Indian Lime Oil Sales Company Limited, to market their product through this cooperative sales organization, and to ask the Comptroller of Development and Welfare in the West Indies to support the efforts of the Association to achieve full cooperation within the industry in the marketing of lime oil. It may be mentioned in this connection that although the West Indian Lime Oil Sales Company Limited handles 75 per cent. of the lime oil produced in the British West Indies, the remainder is marketed competitively through other channels. It is hoped therefore that complete cooperation from all producers in the British West Indies will eventually be secured as this would immeasurably strengthen the position of the industry. The meeting also agreed that standardization of the quality of distilled lime oil was a matter of great importance to the industry and decided that the Inspector-General of Agriculture be invited to consider the appointment of a research officer to carry out an investigation on this matter.

The other marketing problems considered were the coordination and expansion of the trade in limes in Canada, the development of a market for limes in the United Kingdom and the marketing of by-products. In recent annual reports the Trade Commissioner in Canada has repeatedly criticised the methods of marketing adopted by some exporters as unsatisfactory and detrimental to the trade in fresh limes. In the coming season the Trade Commissioner will be given every assistance to develop the more orderly marketing of limes in Canada. The Governments of the Colonies concerned will also be invited to introduce legislation for the standardization of packing materials, grades and sizes as recommended by the Association in due course. With regard to the United Kingdom no development of a trade in fresh limes will be possible until after the war and until the Colonial Empire Marketing Board, which has promised to function as the Association's Advisory Committee in England, has resumed its activities. In the meantime, however, statistics of particular interest to the fresh limes trade will be collected. As far as the by-products of this industry are concerned it was agreed to invite the Inspector-General of Agriculture to arrange for a survey of the present market for such products and for an investigation of their economic possibilities.

Considerable attention was paid by the meeting to the problem of the prevention and control of pests and diseases of limes. At the present time the most serious insect pests affecting the limes industry are the citrus weevil (*Diaprepes* spp.), the Fiddler beetle (*Prepodes* spp.) and scale insects. Investigational work has and is being carried out on all these pests under the Windward and Leeward Islands Citrus Pests Investigation Scheme and certain measures of control have already been recommended. There remains, however, a great deal more work to be done on these pests and the hope was expressed that, after the conclusion of the scheme, the investigations would be continued and form part of the programme of work of any entomological service which might in due course be established under the control of the Inspector-General of Agriculture. As regards diseases, apart from withertip which is still very prevalent, a new disease, of undetermined cause was reported which has destroyed almost all seedling lime trees in Dominica, St. Lucia and Montserrat and is destroying, in the same manner, seedling lime trees in Trinidad. In view of the seriousness of this disease the meeting agreed that its cause was a matter for continued investigation and recommended that the Inspector-General of Agriculture give the subject his careful consideration. The investigation of root stocks in relation to disease resistance and compatibility with the West Indian lime was also recommended. In relation to the possible spread of pests and diseases the Association is to collect all relevant information on the movement of limes and their containers from one Island to another and to invite the Central Plant Quarantine Committee to advise in what way existing regulations might be amended in order to ensure the greatest possible freedom of trade in limes commensurate with effective pest and disease control.

The meeting recognised the need for the establishment and maintenance of a clearing house of information relating to the industry. The details of a form intended for the record of statistics were agreed upon, and the Governments of the colonies concerned are to be invited to furnish the Association with quarterly returns of statistics in accordance with the items listed on the prescribed form for record and circulation to the Island Associations. The information to be circulated will include export statistics, factory data, prospective market conditions and the distribution and annual severity of pests and diseases in the industry. The Agricultural Advisory Department of the College will, for the time being, undertake, as far as possible, the functions of the clearing house.

LAND PRODUCTIVITY MAP OF TRINIDAD, B.W.I.

Copies (price: 1*s.* per copy, post free) of The Tentative Land Productivity Map of Trinidad referred to in Professor Hardy's article on "A Provisional Classification of the Soils of Trinidad" which appeared in the 1940 August issue of this Journal may be obtained on application to the Editor, *Tropical Agriculture*, Imperial College of Tropical Agriculture, St. Augustine, Trinidad, B.W.I. Separate copies of the Table at 3*d.* each can also be supplied.

WITCHES' BROOM DISEASE INVESTIGATIONS.

I. Seasonal Variations in Intensity of Infection and their Effect on Control Methods.

By
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Shortly after witches' broom disease (*Marasmius perniciosus* Stahel) of cacao was discovered in Trinidad in 1928 the Department of Agriculture took over the property now known as Marper Estate in order to carry out field experiments on the disease. This estate, which is on the eastern side of Trinidad, includes one of the areas where the disease was first found, and is now in the centre of a large block of heavily diseased cacao, which makes it very suitable for experiments of this nature. Continuous records of witches' broom formation have been kept since 1930 and from time to time other valuable experiments have been carried out. None of these results has been published up to now, and, as many of them have recently been confirmed and amplified by the work of the Imperial College at River Estate and at Sangre Grande, they have been reviewed in this article.

Seasonal Variation.

It has long been realised in Trinidad that the number of witches' brooms produced on a tree varies from month to month, so that at certain times of the year young brooms are abundant and at other times they are very rare. This is clearly illustrated in Table I and Fig. 1 from Marper Estate. Monthly totals of brooms removed over the whole estate are shown from 1930 to 1934. It will be noticed that every year there is a well-marked maximum in February or March and a slight secondary maximum in September or October. A very marked minimum occurs in July. It is probable that in these records many of the smaller 'star-blooms' produced on the flower cushions, which are now known to be infected, were overlooked; this in no way detracts from the value of the records but merely means that the maxima are not as high as they should have been.

Table I.

Marper Estate: Brooms per Month.

Month.	1930	1931	1932	1933	1934
Jan.		24485	13028	10956	10800
Feb.		97492	44457	15112	33279
Mar.		50996	54637	83557	76638
Apr.		10854	16160	23466	17682
May		6758	13139	11633	10564
June	1152	6085	5853	5785	3541
July	813	1917	3423	4853	3077
Aug.	5914	11796	4182	8022	3045
Sept.	12896	17658	9201	13982	7218
Oct.	2711	10505	14883	25276	9582
Nov.	4205	5966	17368	15506	6557
Dec.	20343	6585	16692	7319	12476

Fig. 2 indicates how the intensity of the disease at Marper has increased during the ten years under review. During this period the disease has spread to almost all the cacao growing districts of the island and has become serious in many of them.

During the past five years witches' broom disease has become firmly established in the Diego Martin valley near Port-of-Spain, and by 1939 had become common at River Estate. It was realised at once that the experiments already laid down on this estate could form a particularly favourable basis for investigations on witches' broom disease, and work was started in September 1939. Since then fortnightly counts of the brooms produced on a block of seventy-seven nine-year-old trees have been made with the results shown in Fig. 3. Here again the well-marked maximum in February or March and the minimum in July is evident, and the secondary maximum in September or October which occurred in 1940 shows clearly. The much greater number of brooms found in 1941 is not due to the improved technique of the workers leading to the discovery of more brooms—most of the work was done by the same man— but to favourable conditions for mushroom formation and infection.

All brooms were removed, but the plot is so small, 154 × 98 ft., and is surrounded on all sides by infected trees, that this removal of brooms can have had little effect on the total number of brooms produced in the plot.

In addition to being counted, the brooms found at River Estate have been sorted and classified. Fortnightly totals for fan and chupon brooms (*i.e.* those produced from vegetative buds) and star and cushion brooms (*i.e.* those produced from flower cushions) are shown in Fig. 3.

Figs. 1 and 3 show that there is a very well-marked periodicity in broom formation, and that as this occurs in two such widely different localities as Marper and River Estates it is reasonable to assume that it is fairly general. It is obviously a matter of considerable importance, and experiments are now in progress at River Estate to try and find an explanation for it. Cacao is known to 'flush' in the dry season about February or March and again in September or October, although sporadic flushing occurs at other times. The peak of flower production probably occurs in May, June or July. It may be possible to correlate 'flushing' and flowering with the formation of 'fan' and 'star' brooms respectively: total broom production should similarly be related to mushroom production and spore formation. These relationships will be discussed in detail in a later article.

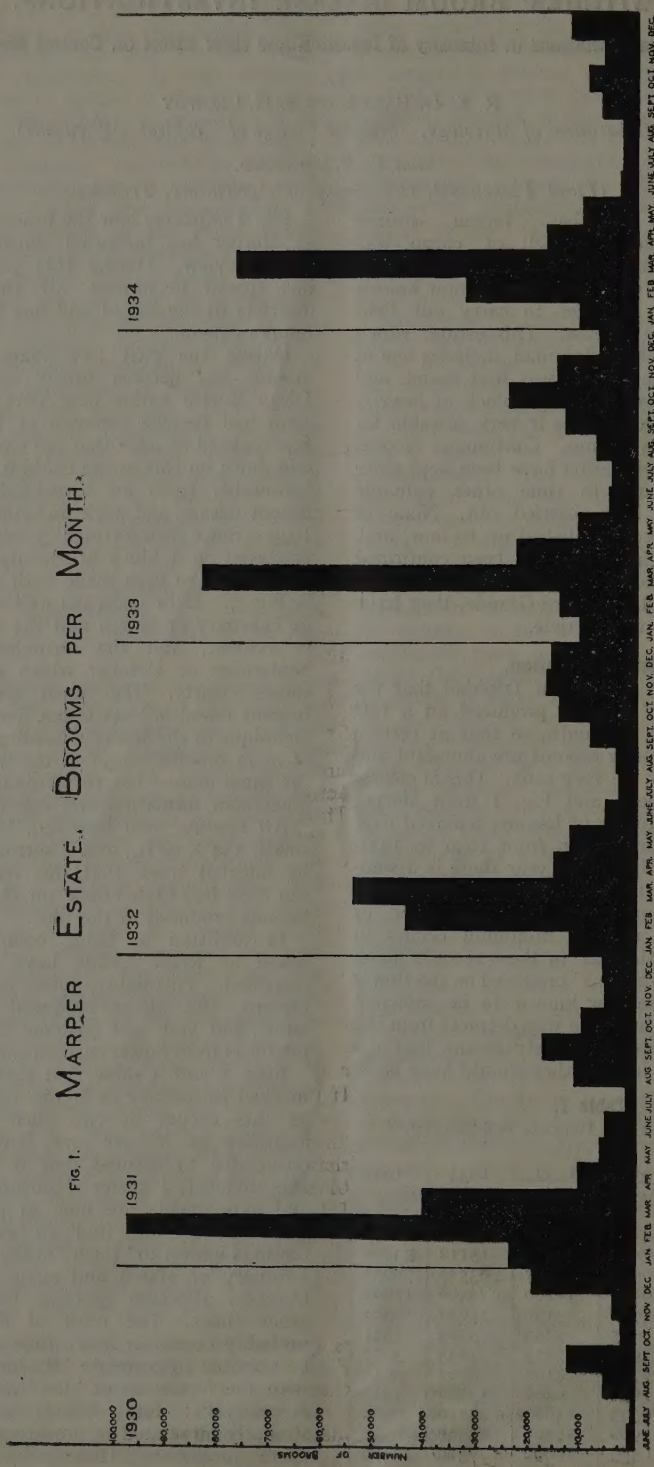
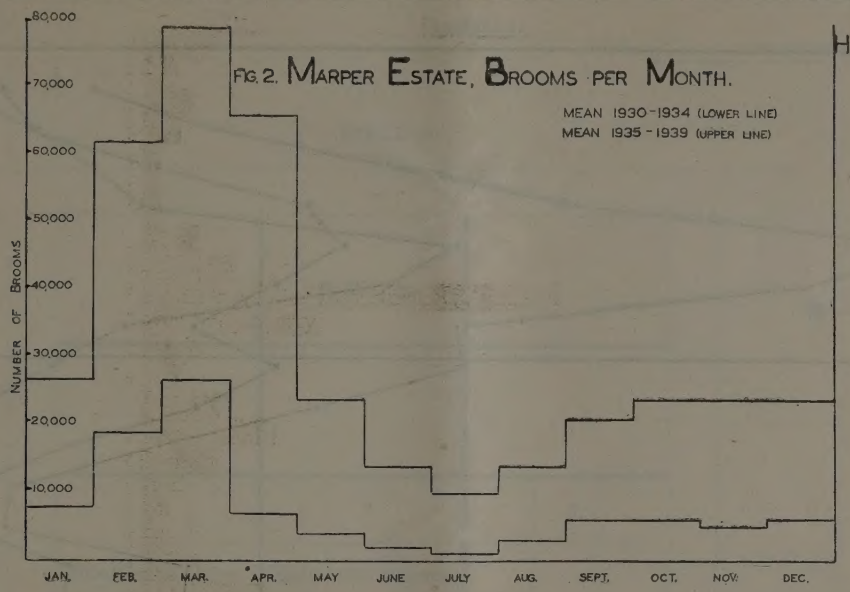


FIG. 1. MARPER ESTATE. BROOMS PER MONTH.



Figures of pod losses due to witches' broom disease have also been kept at Marper since 1932 (Table II). These figures are surprisingly low, only reaching 8.67% in 1937 and 10.0% in 1939. In Table I it is shown that many brooms were removed in 1934, but the loss of pods amounted to only 1.33% (Table II). It would seem that the regular removal of brooms with the consequent prevention of intense spore formation, reduces the loss of pods. It is only when the disease becomes really severe that high percentages of pods are destroyed by witches' broom disease. Losses of 40 to 45% of all pods harvested in a year are not uncommon and losses in individual pickings run as high as 70 or 80%.

Table II.

MARPER ESTATE: PERCENTAGE LOSS OF PODS DUE TO WITCHES' BROOM DISEASE.

Yr.	1932	1933	1934	1935	1936	1937	1938	1939
Loss %	0.87	1.25	1.33	1.31	3.84	8.67	3.51	10.0

Of interest and importance in this connection is the oft repeated question 'To what extent does a heavily diseased field or property infect the surrounding cacao?' The spores of *Marasmius perniciosus* are small, light, and easily blown about and can obviously be carried in the air for long distances. On the other hand they are very susceptible to desiccation and if the relative humidity of the air is much below saturation they quickly lose their viability. It is difficult to imagine how sufficient spores to cause severe infestation of cacao can be brought from far away even when the prevailing wind is favourable, and it has always seemed likely to us that severe outbreaks of the disease are caused by the presence of large numbers of mushrooms actually in the field in question or quite close by.

Recently an opportunity for testing this theory occurred at River Estate. It was noticed that Field 6 was heavily infested with brooms producing mushrooms, and that on the adjoining Field 7 the young two and three-year-old cacao was being severely attacked. Furthermore, brooms appeared to be more numerous on the eastern side of Field 7 near Field 6 from whence the prevailing wind blows. On January 10th and March 6th counts were made plot by plot right across the field from west to east (Diagram 1). Thirty-six plots each of sixteen clonally reproduced trees, or 576 trees in all, were examined with the results shown in Tables IIIa and IIIb and in Fig. 4. The results of the second counting were subjected to statistical analysis with the following results. No significant difference was found between the numbers of brooms produced on each of the six clones (I.C.S. 45, 7, 22, 16, 53 and 1) represented in the experimental area. There was a significant falling off in infection from east to west and a slighter non-significant falling off from north to south. If the totals of brooms on each of the six blocks are compared (Table IV) the results are as follows:—blocks 1, 2 and 3 significantly higher than block 5 which is significantly higher than blocks 4 and 6. A closer examination of Tables IIIa and IIIb shows that the totals for the twelve plots in the two blocks adjoining Field 6 contained in many instances nearly twice as many brooms as plots further to the westward. All the indications are, therefore, that the heavy infection towards the eastern end of Field 7 close to Field 6 is due to the presence of the mushrooms in Field 6. Furthermore, these results indicate that the effect of this centre of infection is only serious for about 100 yards down wind, which may be counted as a comparatively short distance.

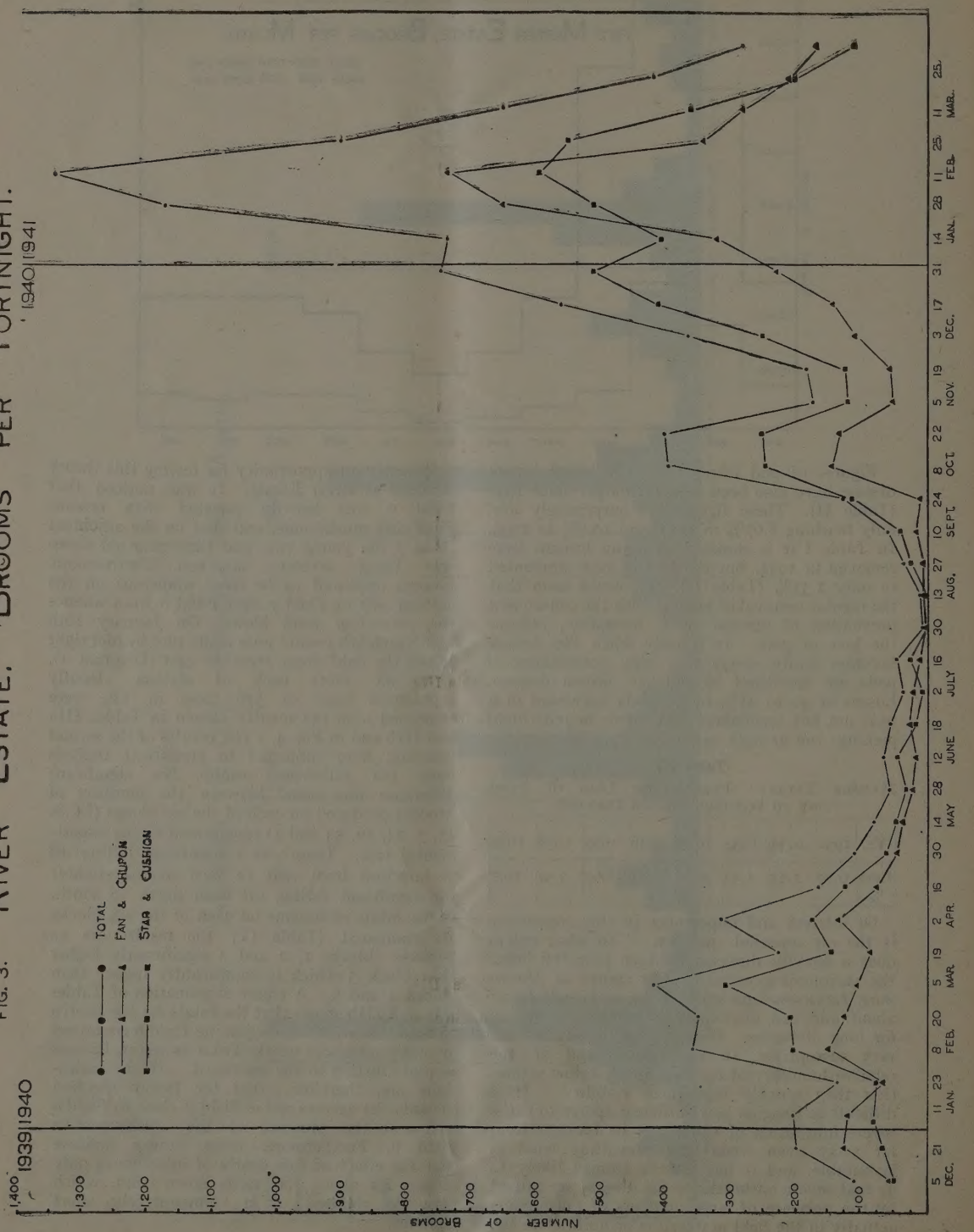


FIG. 3. RIVER ESTATE. BROOMS PER FORTNIGHT.
1940 1941
TOTAL
FAN & CHUPON
STAR & CUSHION
1939 1940
NUMBER OF BROOMS
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
5 DEC.
21
11 JAN.
23
8 FEB.
20
5 MAR.
19
2 APR.
16
30 MAY
14
28 JUNE
12
18 JULY
2
16 AUG.
30
13 SEPT.
27
10 OCT.
24
8 NOV.
22
5 DEC.
19
3 JAN.
17
31 FEB.
14
28 MAR.
11
25

Diagram 1.

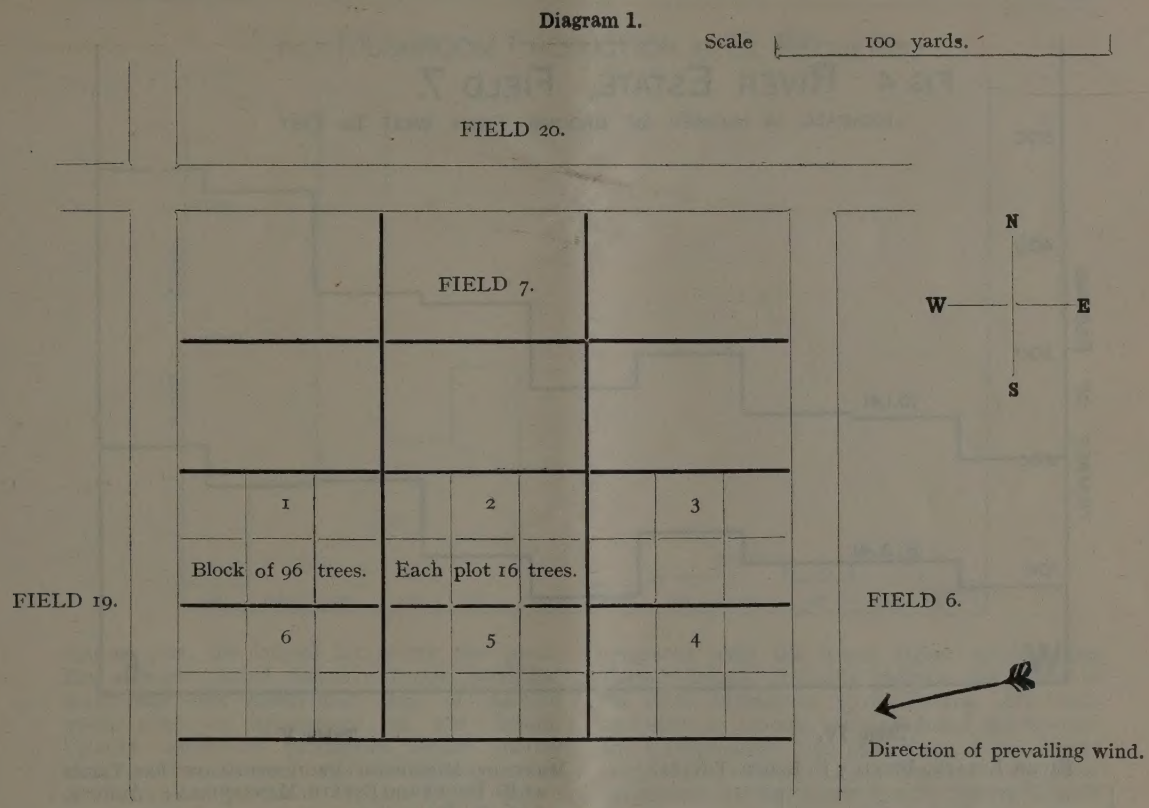


Table IIIa.

River Estate, Field 7: Total Brooms per Plot removed on 10.1.41.

	19	25	39	31	25	32	46	54	43	314	
	29	56	54	54	39	52	33	35	61	413	
W	22	7	4	35	6	20	59	40	63	256	E
	19	28	19	27	13	20	59	60	61	306	
	89	116	116	147	83	124	197	189	228	Totals.	

S

Table IIIb.

River Estate, Field 7: Total Brooms per Plot removed on 6.3.41.

	81	64	105	90	87	107	95	131	128	888	
	49	96	70	114	90	125	86	77	125	832	
W	53	36	40	65	41	58	83	169	129	674	E
	29	56	38	42	64	72	105	89	105	600	
	212	252	253	311	282	362	369	466	487	Totals.	

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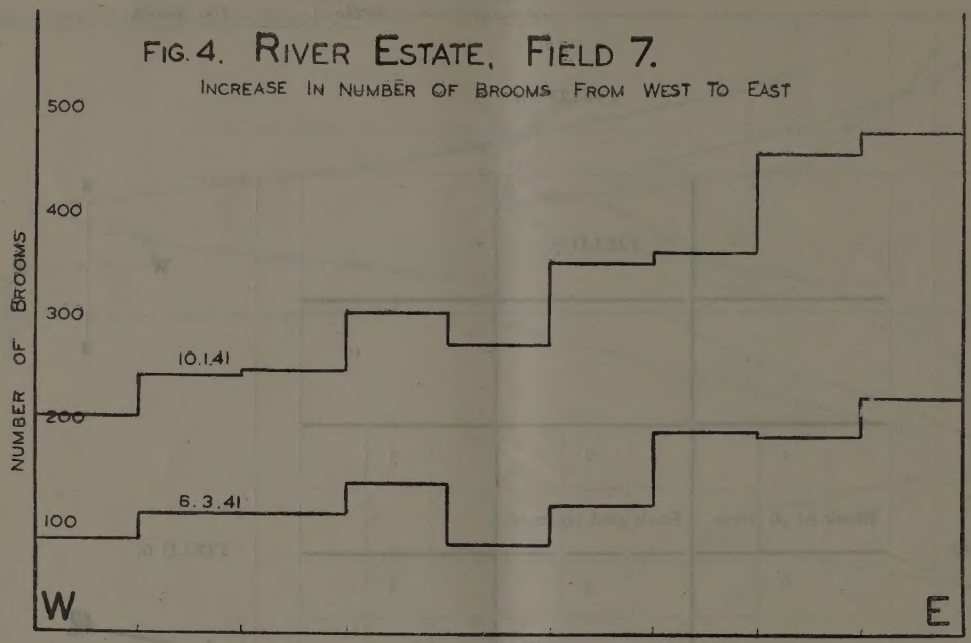

Table IV.

RIVER ESTATE, FIELD 7: BLOCK TOTALS.

	1	2	3	
W	465	613	642	E
	6	5	4	
	252	342	680	

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Result of Statistical Analysis 2, 3, 4, > 1 > 5, and 6.

The formation of the mushrooms of *Marasmius perniciosus* has been studied by the Department of Agriculture at El Recuerdo Estate, Manzanilla in 1936-1937 and at Marper Estate. The Imperial College have carried out similar investigations at River Estate, Diego Martin since September, 1939, and Ste. Marie Estate, Sangre Grande since July, 1940. Table V and Fig. 5 show the monthly mushroom production of 100 trees at El Recuerdo. It will be noted that mushrooms occur most commonly on brooms still attached to the tree, but that they are also produced on the leaves of brooms, on diseased pods, and even on diseased material which has fallen to the ground. Brooms attached to the tree were however obviously the most important source of mushrooms. These figures show that in this wet area mushrooms are formed all the year round but that they are most abundant from September to January, inclusive.

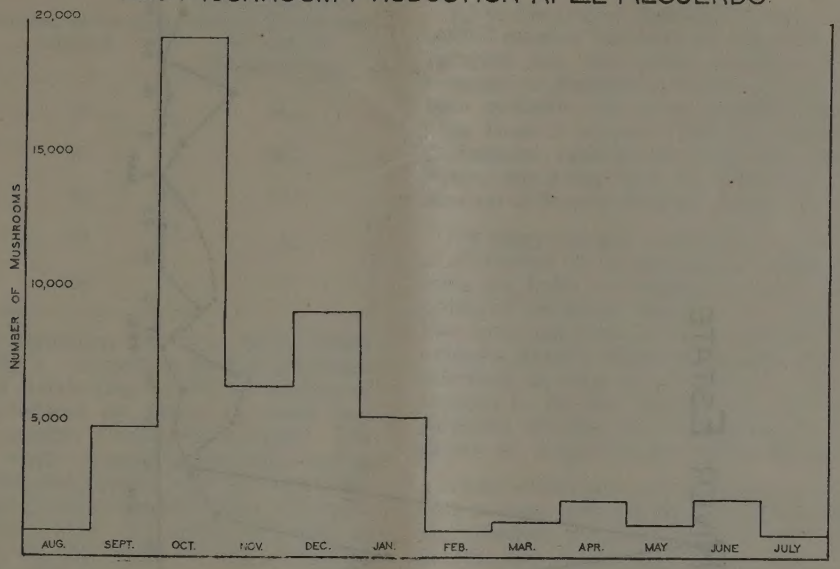
Table V.

MONTHLY MUSHROOM PRODUCTION ON 100 TREES AT EL RECUERDO ESTATE, MANZANILLA: AUGUST, 1936 TO JULY, 1937.

Month.	Number of Mushrooms found				Total.
	On Brooms.	On Pods.	On Leaves.	On Ground.	
Aug.	446	81	483	—	1010
Sept.	2892	51	1862	—	4805
Oct.	13800	174	5421	—	19395
Nov.	4306	69	1998	—	6373
Dec.	8532	127	425	—	9084
Jan.	4838	180	178	—	5196
Feb.	789	18	58	111	976
Mar.	1119	9	82	112	1322
Apr.	1605	25	139	361	2130
May	952	18	44	215	1229
June	1682	23	191	275	2171
July	700	21	54	115	890

Other studies on a small scale were carried out by the Department of Agriculture at Marper Estate, where green brooms were labelled, ten per month, and examined daily. A few brooms dried up after fourteen days, the majority between twenty and twenty eight days, while a few took considerably longer. The decay and final fall of brooms was found to depend to a large extent on their situation on the trees and especially on the degree of protection afforded from wind and rain. Many remained on the trees for more

FIG. 5. MUSHROOM PRODUCTION AT EL RECUERDO



than a year, the longest for nearly two years. The shortest period before a broom produced mushrooms was ninety-four days, or thirteen weeks after the appearance of the broom. Usually mushroom production began shortly after the fifteenth week, and the highest number of mushrooms produced by one broom before it dropped was 283.

More detailed studies of mushroom formation have been carried out at Ste. Marie and River Estates. On River Estate approximately five brooms were tagged each week since September, 1939, and have been examined weekly ever since. The weekly totals of mushrooms produced are shown in Fig. 6. The number of brooms under observation during this experiment varied, as periodically the older ones dropped off and were lost and younger ones started to produce mushrooms. It will be noticed that in a year of low rainfall in this dry area mushrooms were hardly produced at all from March to September, and that the weekly totals fluctuate wildly in the wet weather suggesting a far closer dependence on weather conditions than the Marper or El Recuerdo results indicated. In 1940, January was very dry and none of the brooms labelled in September, October and November, 1939, produced mushrooms before August, 1940. January, 1941, however, was wet enough for considerable mushroom formation and several brooms tagged in September and October, 1940, produced brooms in January and February, 1941. This development of late mushrooms is probably reflected in the exceedingly severe outbreak of disease in February and March, 1941. The shortest time before a broom produced mushrooms was eighteen weeks and the highest number of mushrooms produced by any one broom so far has been eighty. These figures, when compared with the much higher results from Marper Estate, probably indicate the effect of the drier climate at River Estate. All kinds and sizes of brooms have produced mushrooms, and a surprisingly high percentage of the brooms originally labelled, 86%, has done so. In another experiment at Ste. Marie Estate, Sangre Grande in which 175 dry brooms were labelled, 121 or 71% produced mushrooms within six months. On this estate, where the rainfall is much higher than that of River Estate and is comparable with that of Marper Estate, the largest of the experiments on mushroom formation has been set up. Over 500 brooms, of all kinds, were labelled, and have been examined every week. The detailed results of this experiment will be published elsewhere. Noteworthy results are, however, that here again brooms of all kinds (including 'star-blooms') except the very smallest, have produced mushrooms. The shortest time for mushroom production was ten weeks after labelling, six weeks after the broom dried out, but the majority took at least two months longer. The record number of mushrooms produced by any one broom is 302 and the broom has not yet fallen. Table VI shows the percentage of brooms labelled when they were young and green in July, August, September, October and November, 1940, which has produced mushrooms before the 1941 dry season had set in. In all, 22% of the brooms tagged during this period produced mushrooms before the end of February. Similar results were obtained at River Estate where 17% of the brooms labelled since 1st July, 1940, produced mushrooms before the end of February, 1941. The number of mushrooms produced by each broom was, however, always low. All mushrooms were removed and destroyed each week.

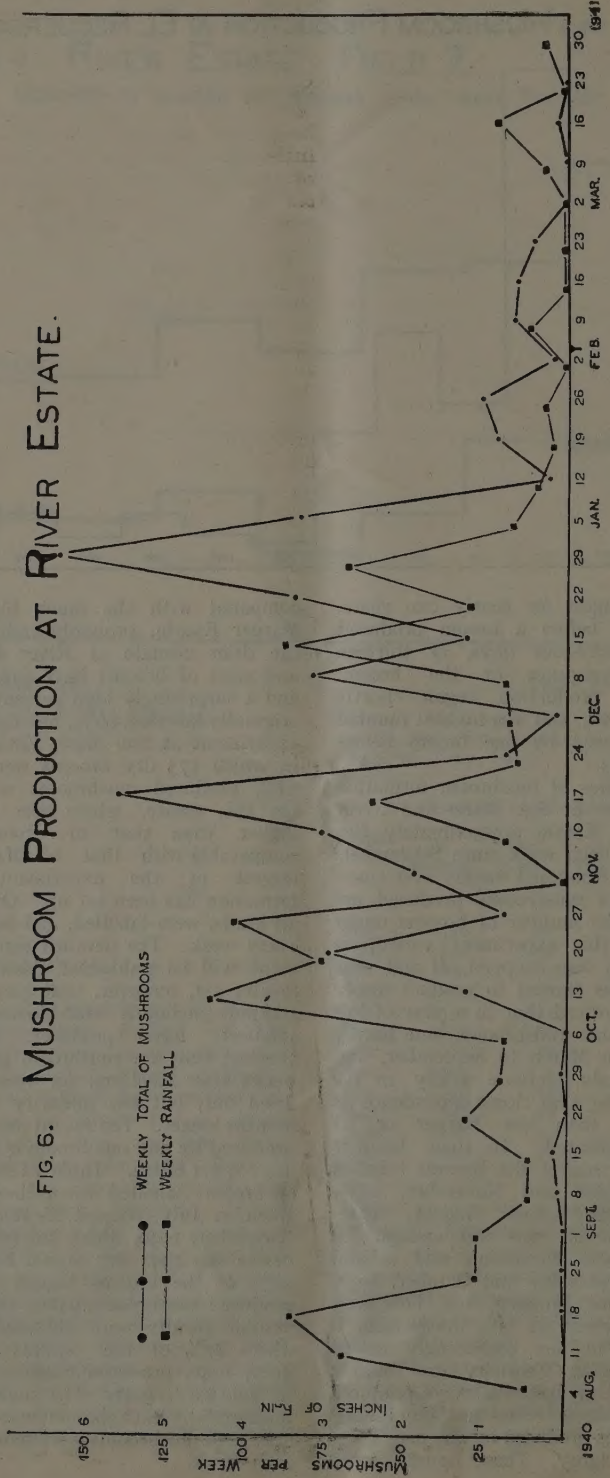


FIG. 6. MUSHROOM PRODUCTION AT RIVER ESTATE.

Table VI.

Month.	Number of Brooms labelled.	Percentage producing Mushrooms by end of February, 1941.
July	26	38.4
Aug.	20	35.1
Sept.	83	19.1
Oct.	70	7.1
Nov.	64	0.0

Mushroom formation on Ste. Marie Estate is shown in Fig. 7. It tends to be more prolonged than at River Estate (Fig. 6) and the number of mushrooms produced per broom per week (not shown in the graphs) is consistently higher. The two maxima which occurred in the weeks ending November 18th and January 27th are interesting as both occurred when rain followed a dry spell. Similar maxima after dry spells occurred at River Estate in the weeks ending November 19th and December 31st.

Figs. 6 and 7 indicate a strong correlation between mushroom formation and rainfall; peaks in mushroom formation often following or coinciding with weeks of high rainfall. A logical inference is that more mushrooms will be formed and consequently infection will be greater in wet districts and in wet years.

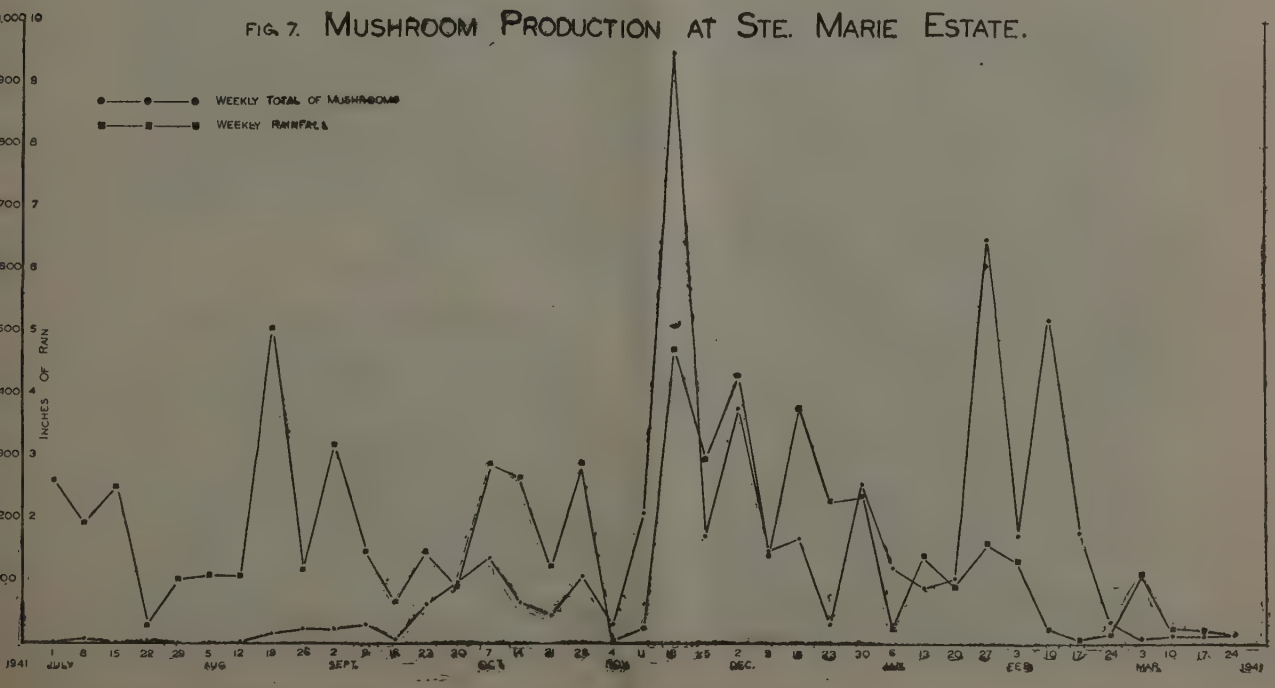
Control Methods.

Up to the present the only seriously attempted control measure has been the removal of brooms. Spraying has not given satisfactory results; resistant or immune varieties of cacao have not been available, and other methods have offered little hope of success. Therefore until resistant or immune varieties are available, *and are in bearing over a large area,* the direct control by the removal of brooms deserves serious consideration.

For many reasons, eradication by the removal of all brooms is an unattainable ideal, since the trees are liable to re-infection from mushrooms produced on fallen brooms. It is possible also that latent infections occur in dormant buds, but evidence recently obtained suggests that if such infections do occur at all they are very rare. It remains to be seen whether by direct control sufficient brooms can be removed to keep the disease at a harmless low level economically.

It was realised some years ago that a broom usually took at least three months to produce mushrooms, and therefore, if brooms were cut out every three months, the disease might be controlled. It has however, proved impossible to put this idea into practice except in isolated instances. The reasons for its failure seem to be threefold—firstly, it is undoubtedly expensive, and the small yields obtained on many properties have been unable to bear the cost of the control measures; secondly, it is difficult, and requires more skilled and supervised work than is often available; and thirdly, it clashes with other operations on the

FIG. 7. MUSHROOM PRODUCTION AT STE. MARIE ESTATE.



estates, such as harvesting, and is therefore neglected. We have therefore reached the conclusion that unless this method can be considerably modified it cannot succeed.

Now, if we consider the control of witches' broom disease by the removal of brooms in the light of the results set out in the first half of this article, certain interesting facts emerge. There are very marked seasonal maxima and minima in broom formation. It is obviously waste of time removing brooms when they are being produced rapidly— it will not stop infection and in a week or two there will be just as many again. Is it not far more logical to concentrate on the period when both broom formation and mushroom production are at a minimum? This minimum occurs in May, June, July and August, broom formation in June and July being especially low. Moreover, it is always easier to spot a dead broom than a green one, and at this time of the year the dry brooms stand out clearly against the young foliage. If, therefore, all possible brooms were removed during these months the disease might be given a severe check, and if this was followed up by a second 'round' in October and November to remove brooms which had been overlooked in June and July or which had developed subsequently, the high maximum in broom formation which would otherwise occur the next February and March might be prevented. Table VI indicates that in wet districts at any rate this second 'round' will be necessary. If this proved successful, control in succeeding years should be easier until the disease becomes stabilised at a harmless low level.

In our opinion, experiments to demonstrate the practicability or otherwise of this suggested scheme should be laid down at once. Furthermore, if after a fair trial the scheme proved to be a failure, the direct control of the disease by the removal of brooms should be abandoned and every effort concentrated on the production of immune or resistant varieties of cacao, and in the search for another and better control method.

Several factors will militate against this control scheme and at least four important questions will have to be settled experimentally if the scheme is to be a success on a commercial scale. These questions are—firstly, is it an economically sound proposition? Will it pay to control the disease in this way? This question cannot be answered except by trial. Secondly, is it humanly possible to remove sufficient brooms in the June-July 'clean-up' to give the desired result? We have indicated in Section I of this article that all kinds of brooms, including small ones, can produce mushrooms, and furthermore, it is well known that even the most careful workers leave brooms in the tops of trees which are quite invisible from the ground. We have amply demonstrated this by using a ladder in our experiments. Will careful work render this residue small enough to prove innocuous? Thirdly, what is the effect of wind-blown spores coming from a distance? Can the disease be controlled on one estate if it is neglected on neighbouring properties? The evidence, admittedly incomplete, suggests that it can, but here again experimental verification is required. Fourthly, can cushion infection be controlled? Usually, when a flower cushion is infected it produces a 'star bloom' or 'cushion broom' and dies. Such brooms are removed by cutting them flush with the trunk or branch of the tree. We are not yet satisfied that removal in this way will always eradicate the infection since there may be a slow spread of the fungus in the bark of the tree which can subsequently infect other cushions. If this type of infection does occur, the control of the disease on a tree already severely attacked by 'cushion' brooms may prove impossible. Here again further experimental work is required.

The control methods originally recommended when the disease first appeared in Trinidad could not be based on evidence accumulated over a period of time. This opportunity is taken to suggest a modification of the procedure of direct control, in the light of information gathered in the decade since witches' broom was first recorded in Trinidad.

We have indicated that information on certain important features concerning the control of witches' broom disease is still lacking. However, the observations made in recent years, together with the extensive records obtained at Marper Estate, enable us to suggest a programme for the removal of brooms. This should be thoroughly tested on the field scale. If such trials prove successful, it will be possible to recommend the new control methods for general use with a reasonable chance of success. If the scheme we have suggested proves too difficult or too costly, it is probable that all hope of controlling the disease by the removal of brooms alone will have to be abandoned. The production of immune or resistant varieties of cacao will then be of paramount importance.

A NEW JUTE SUBSTITUTE.

Among the new fibres and threads produced mainly as substitutes for jute, ramie, hemp and similar natural fibres the "Hofa" thread has drawn some attention of the trade. This thread consists of wood fibre stock and viscose, the latter serving as a binder. In contrast to the practice in wood pulp production, the wood fibre stock is entirely freed from "fibre slime" and fine fibre fragments by thorough washing, so that a loose homogeneous fibre structure similar to that of raw cotton results. By suitable spinning and other treatment, a thread resembling horse hair is produced.—(*Current Science*, Vol. IX, No. 12.)

THE GALL MIDGES (DIPTERA, CECIDOMYIDAE) OF ECONOMIC IMPORTANCE IN THE WEST INDIES.

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Introduction.

An account of the biological and economic aspects of the Cecidomyidae or gall midges and the methods of control applicable to these pests has been given in a previous paper (6). With regard to the West Indies, eight species of gall midges were considered as pests of cotton, tomatoes, sorghum, cassava, citrus and mangoes. These were dealt with as regards derivation and geographical distribution, and a brief outline was given of the damage caused and the economic importance of each species.

In the present paper these pests are dealt with at greater length. Accounts are given of their life-histories, as far as these are known, and the parasites reared from these species are recorded. The nature and extent of the damage caused to the various crops are given, the present economic status of the pests considered and suggestions made as to the most practical methods of control. For a more complete bibliography of these species reference should be made to (7).

The sorghum midge (*Contarinia sorghicola* Coq.) and the tomato flower midge (*Contarinia lycopersici* Felt) are regarded as major pests of sorghum and tomatoes, and are undoubtedly the most important Cecidomyid pests occurring in the West Indies. They are, therefore, considered in greater detail than the other species, and the present account includes original observations on their bionomics and economic status as pests in the West Indies. An analysis of infestation of sorghum in Trinidad by *C. sorghicola* in 1938 and 1939 is given and correlated with the yields harvested. The results of surveys of *C. lycopersici* in 1939 and 1940 show that this pest of tomatoes is much more widely distributed in the Caribbean area than formerly supposed. This species has only rarely been mentioned in the literature, and scarcely anything has been published on its bionomics and economic importance as a pest. Observations have been made on this species in Trinidad at intervals from 1938 to 1941, and an account is now presented of the results obtained.

Contarinia sorghicola Coq.

This species is known as the sorghum midge, and was apparently accidentally introduced into the West Indies from the United States sometime prior to 1910, being first reported by Patterson (11) from St. Vincent. It is well known in the United States, where it is the most important pest of sorghum (*Sorghum vulgare* L.). According to Gable *et al.* (9), no variety of sorghum is known to be resistant to the midge, which attacks not only the grain sorghums such as Guinea corn, but the sweet sorghums and broom corns. It is also known to occur on *Sorghum halepense* Pers. (Johnson grass), *S. sudanense* Stapf. (Sudan grass), *Triodia flava* (L.) Hitchc. (tall redtop grass), *Setaria glauca* and *Sieglingia seslerioides*, and probably attacks other wild grasses.

This pest has been reported attacking sorghum in Hawaii, where it was almost certainly accidentally introduced from the United States, and more recently by Cowland (8) in the Sudan. This is the first record of the species in Africa, where damage attributed to the sorghum midge was first observed in 1930. In the West Indies, it has been reported from Curaçao, D.W.I., St. Vincent and the American Virgin Islands. I have found it commonly in Trinidad attacking Guinea corn, broom corn, Sudan grass and Johnson grass. I have also observed it in Curaçao attacking Guinea corn.

Although sorghum is not extensively grown in the West Indies, except in Haiti and in some of the other islands with drier climates, such as Curaçao and to some extent Barbados, the sorghum midge is undoubtedly to be regarded as its most important pest in this region, and often causes a serious loss of the crop. Dr. J. G. Myers informs me (1940, *in litt.*) that in Haiti sorghum is the chief food-crop of the people. In 1940 at my request, Mr. M. D. ffrench-Mullen kindly made observations on sorghum in Haiti, but did not find any signs of infestation by the sorghum midge, and samples of sorghum, which he sent me, were similarly uninfested.

The larvae of the sorghum midge live within the developing seeds causing them to shrivel and resulting in a characteristic blasting of the spikelets of the sorghum head. In the United States, Gable *et al.* report that the female midge lays about 100 minute white eggs within the flowers of the sorghum heads, attaching them to the inner wall of the glumes. The egg hatches in 2 days and the resulting small larva feeds on the developing seed, changing from a pinkish colour to a distinct red when fully grown and about to pupate. An infestation of a single larva per spikelet is sufficient to cause complete loss of the grain, but two or more larvae may live within the same seed. Pupation takes place within the seed. The larval stage lasts from 7 to 11 days and the pupal stage 3 days, depending on temperature and other factors. Under normal summer temperatures in the United States the life-cycle requires from about 12 to 16 days.

Observations have been made on the biology of this species in Trinidad, and the details of the life-history appear to agree closely with those in the United States. The length of the life-cycle in Trinidad is about 12 days, and during the 2 to 3 months in the dry season when sorghum may normally be in seed and available as a host, there are probably about 6 generations of the midge. During the rest of the year the midge population is maintained on out-of-season volunteer sorghum and on wild host plants, which fact has an important bearing on control.

It is of interest to note that prior to emergence the pupa penetrates the seed coat and projects from the seed. When the adult is liberated, the empty pupal case remains attached externally to the seed. The projecting empty pupal cases, which are silvery-white in appearance, are quite conspicuous on close examination, and their presence is diagnostic of infestation by the sorghum midge. Many of these pupal cases blow away or are shaken from the seeds, but usually a sufficient number remain to be recognised and to enable a diagnosis to be made.

The males appear to emerge rather earlier than the females, and the sex ratio shows more females than males. Mass emergence occurs in the early morning. Mating takes place soon after emergence and this is followed immediately by oviposition by the females. The females are most active during the early part of the day, when they can be observed busily ovipositing in the sorghum flowers. The life of the adult is brief and does not exceed 2 days. The fully grown larva measures 1.75 to 2.25 mm., the pupa about 2.25 mm., the male midge 1.5 to 1.75 mm. and the female 2 to 2.25 mm. in length.

Guinea corn and broom corn have been grown on the College Farm at St. Augustine, Trinidad for many years both on a field scale and on students' demonstration plots. Both crops are usually sown between October and December and harvested about 3 or 4 months later in the dry season between January and April. Records of yields for the past 10 years show that for Guinea corn the average is about 900 lbs. per acre for fields and about 1,680 lbs. per acre for students' plots, and for broom corn about 1,430 lbs. per acre for students' plots. In the case of Guinea corn the crop has occasionally failed completely or produced yields as low as 400 lbs. per acre in bad years and as high as 2,700 lbs. per acre for fields and 4,000 lbs. per acre for students' plots in good years.

Complete failure of the crop has usually been attributed to the depredations of flocks of seed-eating birds. The bird chiefly responsible for the destruction of sorghum is the cowbird (*Molothrus bonariensis minimus* Dalmas). This species belongs to the Icteridae or American orioles and is a parasite, as it has the habit of laying its eggs in the nests of small birds, such as the Venezuelan house wren (*Troglodytes musculus clarus* Berl. and Hart.), the washer-woman (*Fluvicola pica pica* Bodd.) and the white-headed widow (*Arundinicola leucocephala* L.), which bring up its young. The cowbird has a sweet note, the male is a glossy blue-black in colour and the female olive-grey. This species usually feeds in flocks and is undoubtedly a serious pest, being extremely destructive to corn, rice, sorghum and other cereals. Other birds which have been observed feeding on sorghum grain are the grey seed-finch (*Sporophila intermedia* Cabanis), the pygmy seed-eater (*Sporophila minuta minuta* L.) and the rufous-winged ground dove (*Columbigallina rufipennis rufipennis* Bona.). The ground dove has been observed feeding especially on seed which has fallen from the sorghum head due to the activities of the cowbird. Mr. L. L. Kerr kindly informed me of his observations on these birds attacking sorghum.

An attempt was made to protect the sorghum from destruction by birds by the use of strings, from which were suspended a number of bright tin lids, hung among the sorghum heads. The lids clashed together in even quite a gentle wind, and Mr. L. J. C. Evans informed me that they seemed to be fairly effective in keeping birds away. The cowbird, however, appears to be bolder than the other birds, and was only deterred from feeding when the birdscare was moving actively.

Despite the attention of birds, fluctuations in the yield of sorghum from year to year are undoubtedly due in large measure to the activities of the sorghum midge, this pest being normally the most important factor contributing to low yields. It is estimated that at St. Augustine, Trinidad the sorghum midge is responsible each year for an average loss of about 25 per cent. of the crop of Guinea corn, and in bad years for probably more than 50 per cent. of the crop. The loss is rather less in the case of broom corn. This was supported by surveys made in 1938 and 1939. Samples of Guinea corn were picked at random in the field, and the percentage infestation by the sorghum midge calculated. The samples were kept in jars for the emergence of the midges, and the seeds not infested, and therefore undamaged, and those destroyed by the pest were counted. The number of emerging adults was also obtained, but this was invariably in excess of the number of seeds destroyed, for occasionally two or more adults emerge from a single seed.

In 1938 the infestation varied from 44 to 59 per cent. with a mean of 50 per cent., and the yields of Guinea corn were 400, 450 and 775 lbs. per acre with a mean of 542 lbs. per acre and of broom corn 1,080 lbs. per acre. In 1939 the infestation varied from 13 to 33 per cent. with a mean of 24 per cent., and the yields of Guinea corn were 1,160 lbs. per acre and of broom corn 1,380 lbs. per acre.

Parasites recorded from the sorghum midge include the Eulophids, *Aprostocetus diplosidis* Crwfd., and a *Tetrastichus* sp. and the Eupelmid, *Eupelmus popa* Gir., in the United States. *E. popa* is also recorded in Curaçao. This species was apparently accidentally introduced from Asia, and is an external parasite attacking both the larvae and pupae of the midge, while the Eulophids are internal parasites of the larvae. The Argentine ant, *Iridomyrmex humilis* Mayr, is recorded as a predator of the pupae, and a fly, *Psilopodinus flaviceps* Aldr., as a predator of the adults.

In Trinidad I have bred *Aprostocetus diplosidis* Crwfd., determined by Dr. C. Ferrière, in considerable numbers from the sorghum midge. Associated with this parasite were the Eulophid, *Ceratoneura petiolata* Ashm., a *Tetrastichus* sp. and a *Eupelmus* sp., determined by Dr. C. Ferrière, who informs me (1939, *in litt.*) that the *Eupelmus* sp. is not *E. popa*, but is near to *E. urozonus* Dalm. In Curaçao I have also found what I believe to be *Eupelmus popa* attacking the sorghum midge in some numbers. In 1938 and 1939 some 1,850 adult midges and 376 specimens of *A. diplosidis* were obtained from seed heads of Guinea corn in emergence jars, the parasites emerging later than the majority of the host species. The rate of parasitism in different seed heads varied from 12 to 33 per cent. with a mean of 20 per cent. in these two years.

Cultural methods of control of a preventive nature are by far the most important measures used against attacks of the sorghum midge. An important factor bearing on control is the presence of sources of infestation outside the sorghum field itself. Johnson grass and other wild host plants are a constant source of infestation, as are also old neglected fields of sorghum in the neighbourhood.

Volunteer and occasional early-flowering plants in the crop itself frequently develop before the main crop comes into flower. These plants are usually heavily infested, and become an important source of infestation for the rest of the crop. In Trinidad it has been noticed that the young flowers of late tillers are usually very heavily infested, and there seems to be no doubt that the midge population builds up through the season. Preventive control to be effective should therefore be practised as early in the season as possible.

It has been found in the Sudan that sorghum shows no damage when flowering takes place before the middle of September, 50 per cent. damage when flowering occurs in October and 100 per cent. damage when flowering occurs in November. In the United States the early planting of sorghum is recommended as one of the most effective means of reducing losses due to the sorghum midge, but it is uncertain whether this measure will result in a permanent reduction in infestation over a period of years.

An interesting control measure practised in India against a nearly related species attacking sorghum is by means of a cloth, two or three yards in width, covered with an adhesive and carried like a canopy over the crop, which is shaken so that the adults are disturbed and fly upwards, where they are caught on the adhesive. This method would naturally be most effective at the period of maximum emergence of the pest.

Control measures against the sorghum midge in the West Indies should be directed along the following lines, the times of planting and harvesting referring to Trinidad. The crop should be planted as early as possible in October and harvested as soon as possible in January or February. The whole crop should be planted at the same time; if an early crop is planted in October and later crops in November and December for harvest in March and April these will be liable to much heavier infestation. The flowering of the crop should be as uniform as possible and volunteer and early-flowering plants should be suppressed. A close season should be established from March to September, when all growing sorghum should be effectively destroyed or at least prevented from flowering. Finally, as far as practicable, Johnson grass and other wild host plants should be eliminated.

I am indebted to Professor E. Harrison for a number of suggestions, Dr. E. M. Chenery for assistance in the identification of the birds attacking sorghum, and Mr. D. M. Hanschell and Mr. L. J. C. Evans for supplying me with information on the yields of Guinea corn and broom corn grown on the College Farm at St. Augustine.

Contarinia lycopersici Felt

This species is known as the tomato flower midge, and is undoubtedly one of the most important gall midge pests in the West Indies. In earlier papers (6, 7), I stated that it appears to be endemic to the Lesser Antilles and does not seem to be very widely distributed. I have now had to alter my opinion, as this species is much more widely distributed than at first supposed, and I now have to report it from both South and Central America as well as the West Indies.

The tomato flower midge has been reported from St. Vincent, Trinidad, Barbados and Hawaii. The record from Hawaii is of *C. solani* Rübs., but Barnes (3) is of the opinion that this was an erroneous determination, the species being in fact *C. lycopersici*. The account of the habits of the midge and the description of the damage caused to tomato flower-buds in Hawaii agree exactly with what has been observed in the West Indies. This is of interest as the only record of this species outside the neotropical region.

In 1939 and 1940 surveys were made of this pest, and samples of tomato flowers were sent to me for examination from many parts of the West

Indies and elsewhere. The results of these surveys are given in Table 1, and show that the pest occurs in the Caribbean area, not only in Trinidad, Barbados and St. Vincent, but also in Grenada, St. Lucia, Dominica, British Guiana and British Honduras. Further surveys will probably show that it is even more widely distributed. *C. lycopersici* was not found in samples of tomato flower-buds from Tobago, Montserrat, St. Kitts, Jamaica, Bermuda, Curaçao and Haiti, but this does not mean that it is necessarily absent from these places (*see* Fig. 1).

Table 1.

DISTRIBUTION OF THE TOMATO FLOWER MIDGE (*Contarinia lycopersici* Felt), LARGELY FROM 1939 AND 1940 SURVEYS.

Locality.	Year of collection.	Tomato flower midge present.	No. of flowers examined or author.
Trinidad ...	1932	Yes	Briant (5)
	1938	Yes	20
	1939	Yes	177
	1940	Yes	144
	1941	Yes	100
St. Vincent ...	1911	Yes	Patterson (11)
Barbados ...	1935	Yes	Tucker (13)
	1940	No	100
Hawaii ...	1907	Yes	Barnes (3)
Grenada ...	1939	Yes	51
	1940	Yes	26
St. Lucia ...	1939	No	69
	1940	Yes	71
Dominica ...	1939	No	54
	1940	Yes	54
British Guiana	1940	Yes	87
British Honduras ...	1940	Yes	72
Tobago ...	1939	No	63
	1940	No	80
Montserrat ...	1939	No	50
	1940	No	50
St. Kitts ...	1940	No	46
Jamaica ...	1940	No	98
Bermuda ...	1940	No	62
Curaçao ...	1940	No	28
Haiti ...	1939	No	121

I am indebted to the following who, by sending me samples of tomato flowers, made these surveys possible: Mr. C. C. Skeete, Assistant Commissioner of Agriculture for the Leeward and Windward Islands, who was instrumental in samples being obtained from Mr. W. O'B. Donovan, Agricultural Superintendent, Grenada, Mr. E. T. Ward, Agricultural Superintendent, St. Lucia, Mr. F. G. Harcourt, Agricultural Superintendent, Dominica, Mr. R. E. Kelsick, Agricultural Superintendent, St. Kitts, and Mr. W. E. Bassett, Curator, Montserrat; Mr. T. A. Russell, Director of Agriculture, and Mr. J. M. Waterston, Plant Pathologist, Bermuda; Mr. J. F. Ward, Agricultural Officer, British Honduras; Mr. L. D. Cleare, Entomologist, British Guiana; Mr. W. H. Edwards, Entomologist, Jamaica; Mr. R. W. E. Tucker, Entomologist, Barbados; Mr. M. D. ffrench-Mullen, Haiti; Mr. L. Whitlock, Tobago; and Mr. B. A. Bitter for assistance during my visit to Curaçao.

The larvae of the tomato flower midge infest and cause considerable injury to tomato flowers, as a result of which they either wither and are then often shed or the ovary is damaged, resulting in a malformation of the fruit. This pest has only been found attacking tomatoes, and no alternate host plants are known. Patterson (11) and Briant (5) give brief descriptions of the nature and extent of the damage caused by this pest in St. Vincent and Trinidad respectively, and Tucker (13) states that in Barbados this species causes considerable damage to, and premature shedding of, tomato flowers, and damages and deforms the fruit which sets.

Brief accounts of the life-history of this species have been given by Patterson in St. Vincent and Briant in Trinidad. Further observations have been made recently in Trinidad to confirm these accounts and add to what is known of the bionomics of this pest. The life-history appears to be similar in many respects to that of the flower-bud maggot of cotton (*Contarinia gossypii* Felt).

The female midge lays a large number of minute eggs in the early evening in young tomato flower-buds, which are attacked when they are very small, usually only about 1 to 2 mm. in length. The number of eggs laid by a single female is not definitely known, but, from what is known of closely related species, it is probably not less than 100.

Some observations were made in July 1939 at St. Augustine, Trinidad on the time of day at which the midge oviposits. On a number of evenings females were seen with their ovipositors inserted in flower-buds apparently engaged in egg-laying. As many as 10 midges were noticed on one occasion ovipositing in the flowers of a single tomato plant. Midges were not observed egg-laying before 5.30 p.m. and usually continued until about 6.45 p.m. At this time of the year the light intensity diminishes rapidly from about 6.30 p.m. onwards and Lampyrid fire-flies usually come

DISTRIBUTION OF THE TOMATO FLOWER MIDGE (CONTARINIA LYCOPERSICI FELT) IN THE WEST INDIES AND ADJACENT COUNTRIES

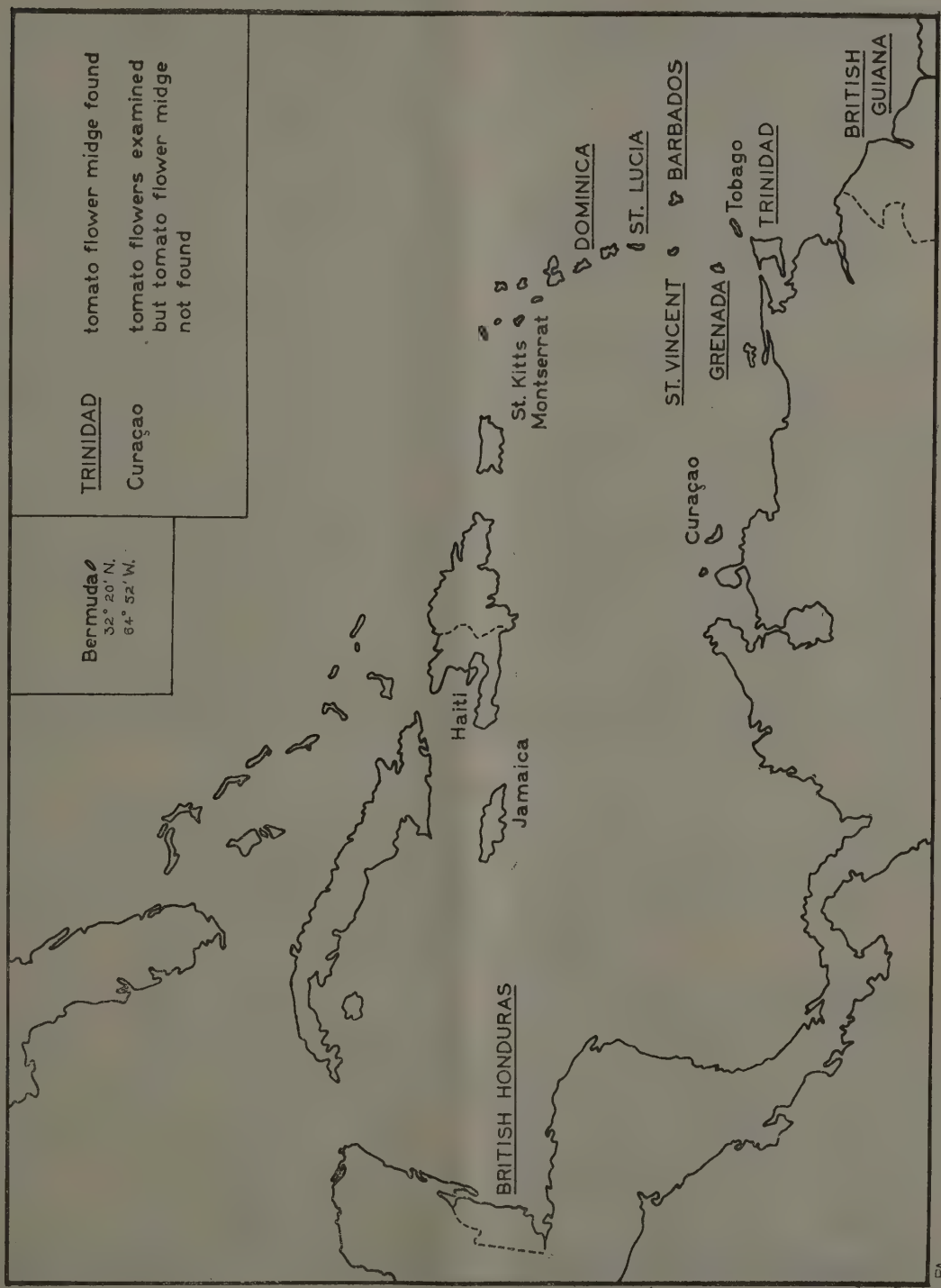

Fig. 1

out in great numbers at about 6.45 p.m., flashing their lights close to the ground. At 6.50 p.m. it was too dark to see insects as small as the tomato flower midge. Observations were continued by means of an electric torch on one evening after dark at 7.30 p.m., and at half-hourly intervals until 11 p.m., but, although midges were occasionally seen, they did not appear to be egg-laying.

The eggs probably hatch in about 2 days or less, and the resulting minute larvae feed on the essential parts of the flower, especially the anthers and frequently also the style and ovary. Patterson records that 5 to 6 or more larvae may inhabit a single flower, and Briant states that there may be as many as 8 or 10.

Attempts were made at first to count the number of larvae infesting a single flower-bud by dissecting the bud with small dissecting needles under a binocular microscope. This was found to be somewhat slow and rather laborious, particularly as the larvae often jumped away. It was found that a much quicker and more accurate method was to drop the flower-bud into 90 per cent. alcohol in a small petri dish or solid watch-glass, and then dissect it, the alcohol inducing the larvae to leave the flower and preventing their escape. The larvae were then separated from the remains of the flower and quickly counted without difficulty under a binocular microscope using a black background and reflected light.

In all 1,623 tomato flower-buds were dissected and I am much indebted to Mr. S. Daniel for assistance in examining the numerous samples sent me. Of 572 flowers examined from Trinidad, Grenada, St. Lucia, Dominica, British Guiana and British Honduras 107 (18.7 per cent.) were infested with larvae of the tomato flower midge. In one sample from Trinidad 83 per cent. of the flowers were infested, and two other samples showed flower infestations of 45 per cent. In the 1939 sample from Grenada 33 per cent. of the flowers were infested and in the 1940 sample 27 per cent. I have found as many as 60 larvae in a single flower, but this is exceptional. Dissection of the 107 infested flowers showed that the average number of larvae per infested flower in any one sample varied from 2.5 to 16 with a mean of about 7 larvae per flower (*see* Table 2).

When only one or two larvae are present in a flower-bud the injury may not be very severe. A greater number of larvae, however, causes the injury to take the form either of shedding of the flowers or of damage to the ovary, which results in a malformation of the fruit. Flowers with more than about a dozen larvae are usually completely destroyed, the developing perianth as well as the essential organs being reduced to a black sodden mass.

At first the larvae are white, but, as they feed, they become pale yellow and, when fully grown and about to pupate, are a bright yellow in colour. They have the characteristic habit of jumping. This is effected by the body being curved in the form of a loop and then being suddenly released, by which they are projected an appreciable distance. When fully grown the larvae leave the flower-bud, make their way to the ground by jumping and enter the soil, where they pupate at a depth of about ½ inch. The larvae are very susceptible to humidities much below atmospheric saturation, not only failing to pupate, but being

Table 2.

PERCENTAGE INFESTATION OF TOMATO FLOWERS BY THE TOMATO FLOWER MIDGE (*Contarinia lycopersici* Felt) AND AVERAGE NUMBER OF LARVAE PER INFESTED FLOWER.

Locality.	Month and year of collection.	No. of flowers examined.	No. of flowers infested.	No. of flowers uninfested.	No. of larvae found.	Average No. of larvae per infested flower.	Infestation of flowers. %
Trinidad ...	June, 1938	20	9	11	147	16.3	45
	June, 1939	10	2	8	12	6.0	20
	July, 1939	30	25	5	282	11.3	83
	Sept., 1939	88	1	87	6	6.0	1.1
	Nov., 1939	49	1	48	3	3.0	2.0
	Dec., 1940	40	18	22	104	5.8	45
Grenada ...	Aug., 1939	51	17	34	99	5.8	33
	Aug., 1940	26	7	19	21	3.0	27
St. Lucia ...	Aug., 1940	71	5	66	25	5.0	7.0
Dominica ...	July, 1940	54	11	43	53	4.8	20
British Guiana...	Aug., 1940	87	4	83	10	2.5	4.6
British Honduras	Aug., 1940	46	7	39	25	3.6	15

killed when kept under relatively dry conditions. This was shown clearly in March 1938 by experiments using apparently fully grown larvae removed from flowers.

In the first experiment, 30 larvae were placed between layers of damp blotting paper in a petri dish, under conditions practically of atmospheric saturation (100 per cent. R.H.). After 3 days all the larvae were alive and after 7 days there was no mortality, although no larvae had pupated. In a second experiment, 30 larvae were placed on dry blotting paper in a petri dish covered with fine-mesh muslin under conditions of varying atmospheric humidity. During the course of the experiment the humidity varied from 50 to 100 per cent. R.H. A humidity approaching saturation was maintained for about 6 out of the 24 hours, and a relatively low humidity, *i.e.* below 60 to 70 per cent. R.H., for about an equal period. Minimum humidities of 50 per cent. R.H. were only recorded on 2 out of the 3 days of the experiment, and lasted for less than an hour at about midday. After 3 days under these conditions all the larvae were dead. In a third experiment, 20 larvae were placed on fine damp soil in a petri dish covered with a glass plate sealed with vaseline, under conditions approaching atmospheric saturation. After 3 days pupae were found in the soil, and after about 10 days adults emerged.

No breeding experiments were carried out, but a successful technique was developed for rearing adults from the larvae. The method consisted of placing either infested flowers or fully grown larvae removed from flowers on the surface of fine damp soil in a deep petri dish. The dish was filled with soil to a depth of about ¾ to 1 inch and covered with a circular glass plate, vaselined to make a sealed connection with the edge of the dish, in order to prevent the drying out of the soil. When fully grown larvae were placed on the soil they immediately burrowed beneath the surface. Pupae were found on examination in the soil at a depth of about ½ inch. Damp soil was found to be essential for pupation, but it was found that thoroughly wet soil was unsuitable. When dry soil was used, the majority of larvae died, but the remainder did not pupate, and a few resting larvae (possibly in a diapause) could be found in such soil after two or three weeks. In all 46 adults were reared; 36 of these had a pupal stage of from 9 to 10 days and the remaining ten from 11 to 12 days. The emergence of adults and the approximate duration of the pupal stage are shown in Table 3.

The larval stage probably lasts from about 8 to 10 days and the pupal stage from 9 to 10 days, although it may be as long as 12 days. The length of the life-cycle is therefore not definitely known, but probably requires from about 18 to 22 days, depending on temperature and other factors.

Table 3.

EMERGENCE OF ADULTS AND APPROXIMATE DURATION OF THE PUPAL STAGE OF THE TOMATO FLOWER MIDGE (*Contarinia lycopersici* Felt) AT ST. AUGUSTINE, TRINIDAD IN 1938.

Date experiment started.	No. of infested flowers.	No. of apparently fully grown larvae.	No. of adults emerged.	Date of emergence of adults	Approximate No. of days in pupal stage.
26 March	—	20	15	5 April	10
11 May	10	—	3	23 May	12
20 May	—	18	9 3	29 May 1 June	9 11
20 May	18	—	12 4	29 May 1 June	9 11

Soon after emergence of the adults mating takes place, and this is followed immediately by oviposition by the females in suitable flower-buds. The length of life of the adult is very short and probably rarely exceeds about 2 days. The fully grown larva measures 1.5 to 2 mm., the pupa about 2 mm., the male midge 1 to 1.25 mm. and the female 1.25 to 1.5 mm. in length.

Patterson (11) records that in St. Vincent no parasites of the tomato flower midge were found. In Trinidad I have found the Platygasterid, *Sactogaster* sp., determined by Dr. C. Ferrière, constantly associated with this species, and on one occasion 5 specimens of this parasite were reared from this host. Whenever tomato plants have been examined in Trinidad, I have observed this parasite actively exploring the flowers at all times of the day, unlike the midge, which has only been seen in the evening when ovipositing in the flower-buds. In both the 1939 and 1940 samples of tomato flowers from Grenada, Platygasterids were found, which appear to be identical with *Sactogaster* sp. from Trinidad, but no parasites were found in the samples from other places.

Briant (5) states that in Trinidad tomato flowers are very liable to be shed by the premature development of the abscess layer in the pedicel, as a reaction to various environmental and physiological factors. Although the reasons for shedding are little understood, it is usually ascribed to be the result of fungal infection, or of unfavourable conditions of temperature, soil fertility or soil humidity. Briant notes that, in addition to possible fungal infections and physiological disturbances, a considerable amount of flower destruction is caused by the tomato flower midge.

My observations in Trinidad not only support this view, but I am forced to the conclusion that this pest is responsible in large part for the shedding of flowers attributed in the past to pathogens and to climatic and edaphic factors. These factors

probably play their part in flower destruction, but I believe that the tomato flower midge is normally the most important agent causing destruction of flowers and consequent loss of crop. Infestations may be as high as 83 per cent., and the majority of flowers attacked are almost always severely damaged if not completely destroyed, depending on the number of larvae present in each flower (*see* Table 2).

Such ecological observations as have been made show that the larvae of the tomato flower midge are very susceptible to humidities much below atmospheric saturation. Experiments show that they are killed by exposure for any appreciable length of time to a humidity of below 60 to 70 per cent. R.H. Damp soil is essential for pupation, and, when dry soil is used in experiments, the majority of larvae die and the remainder fail to pupate. On purely ecological grounds, therefore, the pest would be expected to occur and to be sufficiently abundant to cause damage of economic importance in places with a high rainfall, and to be absent or present only in small numbers in places with a low rainfall.

In view of the small size and number of the samples of tomato flowers examined in the 1939 and 1940 surveys, generalizations cannot at this stage be made as to the ecological and other factors limiting the distribution of this pest. It is nevertheless interesting to note the apparent correlation between distribution and rainfall. Trinidad, St. Vincent, Grenada, St. Lucia, Dominica, British Guiana and British Honduras, in which the tomato flower midge occurs, have a mean annual rainfall of from 74 to 95 inches with an average of 82 inches for the group.* Tobago, Montserrat, St. Kitts, Jamaica, Bermuda, Curaçao and Haiti, in which the tomato flower midge has not been found, have a mean annual rainfall of from 25 to 77 inches with an average of 59 inches for the group.* On the whole, therefore, the countries in which the tomato flower midge occurs have a higher rainfall than those countries from which samples of tomato flowers were obtained and in which the pest was not found.

The only exception appears to be Barbados, which has a lower rainfall than any of the other places in which the pest has been found. Mr. R. W. E. Tucker informs me (1940, *in litt.*) that, since the attack in Barbados in 1935, the tomato flower midge does not seem to have troubled tomato growers, and suggests that the pest probably maintains itself at a low population level, which does not cause growers to complain. The fact that the pest was not found in the 1940 sample of 100 tomato flowers from Barbados (no sample was taken in 1939) supports this view to some extent.

* Mean annual rainfall figures obtained from Climatological Data (1939), U. S. Dept. of Agric., Weather Bureau, West Indies and Caribbean Service, Puerto Rico, **19** : 104.

Tomatoes are usually only grown in Trinidad during the dry season, and observations show that there are very few larvae of the tomato flower midge in the flower-buds at this time. During the rainy season, however, the state of affairs is quite different, and almost every flower-bud examined is infested with numerous larvae of this pest. It is generally understood in Trinidad that tomatoes cannot be grown successfully in the rainy season, and I believe the tomato flower midge to be normally the most important limiting factor restricting successful tomato production to the dry season.

Cultural methods of control are by far the most important measures used against gall midge attacks. They are based on a knowledge of the ecology of the insect, and aim at modifying cultural practice, so as to place the pest at a disadvantage. Control measures of this nature against the tomato flower midge depend on the ecological requirements of the larvae on leaving the flower for pupation in the soil. Damp soil is essential for pupation, and control measures should therefore be directed along the following lines.

The crop should be planted so that flowering occurs only in the dry season, as normally practised in Trinidad. The soil around each plant should be kept well forked, so that the surface layers remain as dry as possible, and the soil should be kept quite free from weeds. During the dry season tomatoes cannot usually be grown successfully without supplying them with water. The water should not be applied so as to wet the surface soil around the base of the plants, but should be applied only between the rows of plants. Another method of supplying water that is suggested is by means of irrigation ditches between the rows of plants, so that water is available for the roots, but the surface layers of soil immediately below and around the plants remain dry. Chemical control by the use of insecticides is only of very limited application against gall midges, but the following suggestions are made for the control of the tomato flower midge by this method. Insecticides such as naphthalene and paradichlorbenzene should be applied to the surface layers of the soil beneath each plant. These substances volatilize comparatively slowly and act as soil fumigants, but considerable amounts have to be used and, under the conditions of high soil temperature obtaining in the tropics, their action does not persist for very long. In this connection Briant (5) reports that in St. Vincent the application of vaporite in large quantities to the surface of the soil appeared to give some slight success as a control measure against this pest. Another method of chemical control suggested is the use of contact insecticides such as nicotine and pyrethrum against the adult midges. These insecticides should be applied to the plants in the form of sprays in the early evening after about 5.30 p.m., when the adult midges are ovipositing in the

flower-buds. These suggestions for chemical control are purely tentative and are not intended to be in the nature of practical recommendations for tomato growers.

I am grateful to Dr. E. C. Humphries for advice on meteorological matters and Miss P. Atteck for Fig. 1 showing the distribution of the tomato flower midge.

Contarinia gossypii Felt

The larva of this species is known as the flower-bud maggot of cotton, first appearing as a pest in Antigua in 1907 and causing serious damage to cotton for two successive seasons. Soon after it made its appearance in Antigua, it was reported in Montserrat in 1909, and since then it has been reported in Tortola in the British Virgin Islands in 1916, in St. Croix in the American Virgin Islands in 1923 and in Florida, U.S.A. in 1932. This is apparently the first record of this endemic Lesser Antillean species on the continent of North America. Wolcott (15) states that the insect probably also occurs in Puerto Rico and Haiti, but this has not been confirmed.

Ballou (1) gives an account of the life-history of this pest, and the following is what is known of its bionomics. The egg is inserted into the young flower-buds of the cotton plant by the female, probably in much the same way as in the tomato flower midge (*Contarinia lycopersici* Felt). When the egg hatches the minute larva is white, but during growth becomes yellowish, and, when fully fed and about to pupate, is pinkish-yellow to orange in colour. More than one female probably oviposits in the same bud, and Ballou states that as many as 43 larvae, varying in size and development, have been found in a single bud. The larvae are found among the essential organs of the flower, feeding especially on the developing stamens. Rainwater (12) states that in Florida the flower-bud maggot attacks not only the flowers of wild cotton but also the squares and bolls, in some instances 100 or more larvae being found in a single boll.

When very young flower-buds are attacked they are shed. Such infested buds almost invariably show a characteristic flaring of the bracts prior to shedding. Older buds are better able to withstand the attack. Their bracts do not usually flare and the buds are not shed, but they are unable to open fully and do not produce bolls. The larvae have the characteristic habit of jumping. The fully grown larva leaves the bud and enters the soil for pupation. On emergence the males and females mate and oviposition follows.

The length of the life-cycle is not definitely known. The egg stage probably lasts about 2 days, the larval stage from 10 to 12 days and the pupal stage from 10 to 14 days. The complete life-cycle, therefore, probably requires from about 22 to 28 days, depending on temperature and other factors. The adults are short-lived; they probably rarely live more than about 2 or 3 days and usually die soon after oviposition. The male gall midge is about 1 mm. and the female about 1.5 mm. in length. The fully grown larva measures 2 to 2.25 mm. in length.

Parasites recorded from the cotton flower-bud maggot in Antigua include the Pteromalid, *Catolaccus* sp., and the Platygasterids, *Sactogaster rufipes* and *Leptacis* sp. The Pteromalid, *Zatropis deuterus* Crwfd., is also recorded as attacking this species, and a *Zatropis* sp. is recorded as a parasite in Florida.

This pest caused serious loss to cotton growers in Antigua from 1907 to 1909, and again in 1913, 1918 and 1919 as well as in Tortola in 1916. There have now been no reports of severe damage for a number of years, and at the present time it can only be regarded as a minor pest of cotton.

Ballou (1) suggests as methods of control the hand picking and destruction of infested flower-buds, the application of a soil fumigant to the surface layers of the soil, the destruction of wild cotton, early planting and other cultural measures. Wet weather with damp soil conditions seems to be particularly suitable for the pupation of the pest, and hot dry weather with dry soil conditions unfavourable. Cultural methods of control, therefore, should be directed to keeping the land free from weeds and the surface soil as dry as possible.

Porricondyla gossypii Coq.

The larva of this gall midge has been called the red maggot of cotton, and first appeared as a pest in Barbados in 1903. Although it is also known to occur in Montserrat, it has not been recorded there as a pest.

Ballou (2) gives a brief account of the life-history of this species as far as it is known, describes the damage caused and makes suggestions for control. The larvae occur in numbers just beneath the bark of the stem, the eggs being apparently laid in wounds and the larvae feeding in the cambium between the bark and the wood. When the attack is severe the stem may be completely girdled, resulting in the death of the terminal part of the shoot. The larvae when fully grown are orange-red to reddish in colour and about 4 mm. in length. They leave the stem to pupate in the soil. Other details of the life-history are apparently quite unknown. No parasites of this gall midge have been recorded.

This pest has on occasion caused serious injury to cotton in Barbados especially in 1905. For many years there have been no reports of severe damage, and at the present time it can only be regarded as a minor pest of cotton.

The prevention of wounds, the cutting out and burning of affected parts as soon as detected and the destruction of all cotton plants immediately after the crop is picked are suggested as methods of control.

Iatrophobia brasiliensis Rübs.

The conspicuous reddish galls, caused by this gall midge on the leaves of cassava (*Manihot utilissima* Pohl), are the frequent subject of enquiry. The species is recorded from Brazil, British Guiana, Trinidad, Tobago and St. Vincent. In Trinidad it is ubiquitous, and galls are sometimes extremely abundant, but it appears to be very much rarer in Tobago.

Houard (10) gives an adequate description of the galls, and Bequaert (4) an interesting account of the biology of the species in Brazil, with excellent figures and photographs of the galls. The galls are found on the upper surface of the leaf in the form of nail-like outgrowths, which may be straight or curved, and attain a length of 11 to 15 mm. and a breadth of 3 to 5 mm. They are smooth, yellowish in colour or pale green frequently tinged with red, the reddish coloration being more pronounced in the red-stemmed varieties of cassava. The wall of the gall is fleshy and the single cavity within opens on the lower surface of the leaf. Each gall contains only a single larva, which is bright orange in colour. Galls may occur on any part of the leaf, being often abundant near the midrib, and, when very numerous, bring about a distortion of the leaf. Fused galls, with either common or separate openings but with fusion of adjacent walls, sometimes occur. Pupation takes place within the gall, the adult midge leaving the gall by the opening on the lower surface of the leaf. The fully grown larva measures 2.25 to 2.5 mm. and the pupa about 2.5 mm. in length. The male midge is 1.5 to 2 mm. and the female 2 to 2.25 mm. in length. The life-history of the species is not known in detail.

Parasites recorded from this species include the Eulophid, *Tetrastichus fasciatus* Ashm., in St. Vincent and the Eulophids, *Aprostocetus fidius* Gir. and *Aprostocetus* sp., in Trinidad. In Trinidad and also in British Guiana, I have bred the parasite, *Tetrastichus fasciatus* Ashm., determined by Dr. C. Ferrière, in considerable numbers from this gall midge.

The galls are usually not sufficiently numerous to affect the development of the plant adversely, although on occasion they may be extremely abundant, the leaves then being completely deformed and the growth of the plant retarded.

When galls are especially abundant their collection and destruction is the only practical method of control which suggests itself, but this is recommended with reserve, as by this means the parasites are destroyed together with the midges.

Erosomyia mangiferae Felt

This species is known as the mango midge and appears to be endemic to the Lesser Antilles, being recorded from St. Vincent and also from plants imported from St. Lucia. According to Patterson (11) the larvae infest and frequently destroy the inflorescences and also cause galls on the young newly expanded leaves of mango (*Mangifera indica* L.) in St. Vincent. Patterson states that pieces of the stem of the inflorescence, only 1 inch in length, have yielded upwards of 100 larvae, and that pupation occurs in the ground.

A gall midge attacking mango inflorescences in Trinidad has been reported by Urich (14). As far as I am aware this species has never been described, but, the account of the nature of the damage as given by Urich agrees so well with that of Patterson, that I feel reasonably certain that the Trinidad and St. Vincent insects are the same species.

Urich gives a brief account of the life-history of this species as far as it is known, describes the nature and extent of the damage caused and makes suggestions for control. The female midge lays an unknown number of eggs in the youngest flower-buds of the inflorescence and also in the youngest leaf-buds. The eggs probably hatch in about 2 or 3 days and the young larvae bore into the plant tissue. Small swellings are formed within which the larvae live, feeding on the plant tissue and eventually causing the young flowers and leaves to dry up and die. The stalks of the flowers are also apparently affected and the injury manifests itself by small decayed spots, through which injurious fungi can invade the plant. The length of the larval stage appears to be from 10 to 14 days. When fully grown the larvae work their way out of the mango shoots and make their way to the ground. They pupate in the soil within small cocoons constructed of silk and particles of earth. The pupal stage apparently lasts about 7 days. The length of the life-cycle is not definitely known, but according to Urich probably requires about 21 to 30 days.

Urich records that the mango midge is attacked by an undetermined parasite, the parasitized larvae of the midge being unable to leave the shoots and the adult parasites emerging from the swellings in the shoots. As a rule this pest is kept under control by natural enemies, presumably parasites, but occasionally causes considerable injury and is capable of destroying both the young mango flowers and leaves.

Urich states that the development of this pest is favoured by a dry season, which is unusually wet, presumably because damp soil is necessary for pupation. This would suggest the application of cultural methods of control directed towards keeping the surface soil as dry as possible. Another method of control suggested is to cover the ground under the trees with lime or any other substance, which would prevent the larvae from entering the soil for pupation.

Asynapta mangiferae Felt

This species may be termed the mango shoot midge, and is only known from Barbados, where it has been reported as a pest of mangoes. The larvae live beneath the bark of small shoots of grafted mango (*Mangifera indica* L.), feeding probably in the cambium and causing the death of the terminal parts of the shoots. The fully grown larvae probably leave the shoots and pupate in the soil as in the citrus shoot midge (*Asynapta citrinae* Felt), but the life-histories of neither the mango nor the citrus shoot midge have ever been studied in detail. This pest appears to be only of minor importance. The cutting out and burning of all infested shoots would probably serve as an adequate measure of control.

Asynapta citrinae Felt

This species may be termed the citrus shoot midge, and is only known from Puerto Rico, where it has been reported as a pest of citrus. The larvae live beneath the bark of grapefruit shoots, mining in the cambium and causing a dark discoloration of the shoots. The fully grown larvae leave the shoots and pupate within cocoons in the soil, and it is reported that adults emerged 4 days after the larvae entered the soil for pupation. Other details of the life-history of this species are apparently quite unknown. The economic status of this pest is uncertain, but it is probably only of minor importance. The only method of control which suggests itself is the cutting out and burning of all infested shoots.

Summary.

1. The following eight species of gall midges are considered of economic importance in the West Indies: *Contarinia sorghicola* Coq. (sorghum), *C. lycopersici* Felt (tomatoes), *C. gossypii* Felt (cotton), *Porricondyla gossypii* Coq. (cotton), *Iatrophobia brasiliensis* Rübs. (cassava), *Erosomyia mangiferae* Felt (mangoes), *Asynapta mangiferae* Felt (mangoes) and *A. citrinae* Felt (citrus).

2. Accounts are given of the life-histories of these species, the nature and extent of the damage caused are discussed and suggestions are made for their control.

3. An analysis of infestation of sorghum in Trinidad by *Contarinia sorghicola* in 1938 and 1939 is given and correlated with the yields harvested.

4. The results of surveys of *Contarinia lycopersici* in the Caribbean area in 1939 and 1940 are given. This pest is now recorded from Trinidad, Barbados, St. Vincent, Grenada, St. Lucia, Dominica, British Guiana and British Honduras. There is an apparent correlation between distribution and rainfall, the countries in which this species occurs having a higher rainfall than those in which it has not been found.

5. An account is given of observations on *Contarinia lycopersici* in Trinidad, the more important of which are the following: The adult midges oviposit in tomato flower-buds in the early evening after about 5.30 p.m. The infestation of flowers may be as high as 83 per cent. The average number of larvae per infested flower varies from 2.5 to 16 with a mean of about 7 larvae per flower. One or two larvae in a single flower cause slight damage, a greater number cause severe injury and more than about a dozen larvae completely destroy the flower. The larvae are very susceptible to humidities much below atmospheric saturation and damp soil is essential for pupation. The most practical method of control is the restriction of tomato cultivation to the dry season and the maintenance of the surface layers of soil in as dry a condition as possible.

References.

(1) Ballou, H. A. (1909).—The flower-bud maggot of cotton (*Contarinia gossypii* Felt). *West Indian Bull.*, Barbados, **10** : 1-28.

(2) Ballou, H. A. (1912).—Insect pests of the Lesser Antilles, Barbados : 52.

(3) Barnes, H. F. (1937).—Check list of the Cecidomyidae of Oceania. *Occas. Papers Bishop Mus.*, Hawaii, **13** : 62, 64.

(4) Bequaert, J. (1926).—Medical Rept. Hamilton Rice 7th Exped. Amazon, Harvard, **2** : 204-209.

(5) Briant, A. K. (1932).—Tomato diseases in Trinidad. *Tropical Agriculture*, Trinidad, **9** : 104.

(6) Callan, E. McC. (1940).—Some economic aspects of the gall midges (Diptera, Cecidomyidae) with special reference to the West Indies. *Tropical Agriculture*, Trinidad, **17** : 63-66.

(7) Callan, E. McC. (1940).—The gall midges (Diptera, Cecidomyidae) of the West Indies. *Rev. Entomologia*, Rio de Janeiro, **11** : 730-758.

(8) Cowland, J. W. (1936).—The sorghum midge in the Anglo-Egyptian Sudan. *Ann. Appl. Biol.*, **23** : 110-113.

(9) Gable, C. H., Baker, W. A. and Woodruff, L. C. (1928).—The sorghum midge, with suggestions for control. *U. S. Dept. Agric., Farmers' Bull.* 1566 : 1-9.

(10) Houard, C. (1933).—Les zoocécidies des plantes de l'Amér. du sud et de l'Amér. cent., Paris : 196-197.

(11) Patterson, W. H. (1912).—Report on the Agricultural School, St. Vincent, 1910-11, 20-23. *West Indian Agric. Reports*, Barbados.

(12) Rainwater, C. F. (1934).—Insects and a mite of potential economic importance found on wild cotton in Florida. *Journ. Econ. Ent.*, **27** : 758-760.

(13) Tucker, R. W. E. (1935).—Rept. on Entomological Section for 1935. *Agric. Journ.*, Barbados, **4** : 65.

(14) Urich, F. W. (1921).—The mango midge. *Bull. Dept. Agric.*, Trinidad and Tobago, **19** : 110.

(15) Wolcott, G. N. (1933).—An economic entomology of the West Indies, Puerto Rico : 285-286

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Studies on Organic Phosphorus Compounds in Soil; Isolation of Inositol.

In a study of the organic phosphorus in cultivated Hawaiian soils, an attempt was made to identify the organic-phosphorus compounds of soil. The results of the investigation may be summarised as follows:—Crystalline inositol was isolated for the first time from organic-phosphorus-bearing soil materials, thus establishing the presence of inositol phosphates in these soils. No evidence of nucleic-acid compounds could be found in any of the soils investigated. An ash-free organic-phosphorus product isolated from soil was resistant to decomposition and gave inositol and phosphoric acid on hydrolysis, and the phosphorus and nitrogen contents suggest the ammonium salt of inositol monophosphate. Quantitative estimations of inositol liberated by hydrolysis showed that inositol-phosphate compounds account for only a part of the total soil organic phosphorus.—(*Soil Science*, Vol. L, No. 2, p. 81.)

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Upward Movement of Salt in the Plant.

A paper by Prof. D. R. Hoagland, T. C. Broyer and P. R. Stout of the University of California, Berkeley, was recently read dealing with the upward movement of salt in the plant, with special reference to the metabolic activities of roots.

Previous investigation has proved that accumulation of salt by the plant from the nutrient medium depends on aerobic metabolism of root cells. The relation of root activities in salt accumulation to movement of salt to the shoot has now been studied from several points of view. For certain purposes it has been necessary to conduct experiments over short periods of time with tracer elements, not initially present in the plant. Bromide ions and salts of the radioactive isotopes of bromine, sodium, phosphorus and potassium have been utilized. One of the authors (P. R. Stout) has developed a technique for showing in graphic manner the general distribution of radioactivity in the plant by effects produced on X-ray films.

Several general cases of salt movement are recognized: (*a*) under influence of root pressure, (*b*) as affected by transpiration, (*c*) movement under conditions conducive to root injury produced by high salt (for example, sodium chloride) concentrations. Xylem exudates may build up very rapidly concentrations of salt much higher than those of the external solution. This may occur even before the roots have attained their maximum capacity for salt accumulation. The phenomenon is related to oxygen supply to roots, concentrations and kind of salt supplied, and indirectly to photosynthesis. Soluble organic nitrogen compounds and organic acid can also move in the exudate dependent on metabolic activities of the root and nature of salt supplied. The effects of $KHCO_3$ are particularly interesting in connexion with organic acid metabolism. Young active barley plants may absorb and translocate nutrient ions almost as readily in the dark as in the light, over brief experimental periods. Such plants may grow normally for some time with nutrients supplied only during the diurnal dark periods. With large plants, or those less capable of developing root pressure, rapid upward movement of salt depends on transpiration, which may thus indirectly influence absorption of salt by the root. Further evidence was obtained on the path and rate of upward and downward movement of phosphate by the use of radioactive phosphorus.—(*Nature*, Vol. CXLVI, p. 340).

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Vitamin B_1 as Growth Promoter.

Because of wide interest in the use of vitamin B_1 (thiamin) for promoting plant growth, some tests were made to determine its effectiveness. Solutions containing various amounts of the vitamin were applied, together with nutrient, to the roots of different kinds of crop plants grown in sand and in soil. In these experiments each treatment was replicated from eight to ten times and distributed evenly throughout the greenhouse bench. Concentrations of vitamin B_1 varied from 0.1 to one part per million. In some experiments it was applied every second day, in others, once a week. *Cosmos*, *Zinnia*, radish, cabbage, *Dahlia*, and sunflower were among the plants used. In some instances, nutrient salts together with B_1 were added to tap water with which the plants were irrigated. In others only distilled water *plus* nutrient salts was used, and extreme care was taken to protect the plants from any source of vitamin B_1 other than that supplied in measured amounts. The vegetative growth of some of the plants, such as *Cosmos*, was controlled by adjusting the daily period of illumination so that one-half the plants received short-day light and differentiated flowers early, while the remainder received long-day light and grew vegetatively for a longer period. In other experiments, the vegetative growth of cosmos was varied by the use of different amounts of nitrogen supplied as part of their fertilizer requirements. In each type of plant, some received vitamin B_1 and some did not.

Although the following factors were varied—kind of plant, amount of B_1 supplied and time of its application, and relative amount of vegetative development and flower production—there was in no case positive evidence that vitamin B_1 increased the growth of roots or tops as measured by dry weight. It did not advance the date of flowering or increase the number of flowers produced per plant. The use of vitamin B_1 for stimulating plant growth under conditions similar to any of those used in these experiments cannot be considered effective.—(*Indus. Eng. Chem., News Edit.*, Vol. XVIII, p. 1071.)